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Effects of Watering Treatments on Germination, Survival, and Growth of Rocky Mountain Douglas-fir: A Greenhouse Study

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Abstract

Amount and distribution of water from 0.0 to 2.0 inches per month affected germination, survival, and growth of Douglas-fir seedlings. Germination increased when increasing amounts of water were distributed evenly during the month, but was not affected when water was applied once a month. Survival was acceptable when seedlings received 1 inch or more of water distributed throughout the month. Seedling growth was increased slightly with 2.0 inches of water per month.

Keywords: *Pseudotsuga menziesii* var. *glauca*, plant-water relations, plant physiology, seed germination.

Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) is considered one of the climax species in montane forests of the central Rockies (Oosting 1956). In Colorado, on the east side of the Continental Divide, the species predominates on northerly aspects between elevations of approximately 6,000 to 9,500 feet (1,830-2,900 m) with lodgepole pine (*Pinus contorta* subsp. *latifolia* (Engelm. ex Wats.) Critchf.) as a major associate and occasional aspen (*Populus tremuloides* Michx.), Engelmann spruce (*Picea engelmannii* Parry), blue spruce (*Picea pungens* Engelm.), and ponderosa pine (*Pinus ponderosa* var. *scopularum* Engelm.). These Douglas-fir forests have major watershed, esthetic, recreation, and wildlife values.

Regeneration success following disturbances is critical to the silviculture and management of these forests. Little information is available concerning reproduction of Douglas-fir in Colorado, but information from other areas indicates that regeneration could be a problem. Previous studies in the northern and central Rockies indicate that moisture can limit Douglas-fir on the more severe sites, especially in the southern range of the species or east of the Continental Divide (Hayes 1965, Ryker 1975). Studies in the Southwest

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further indicate that first-season seedlings are shallow rooted, and few survive to the second year (Jones 1967, 1971). Krauch (1956) also found that Douglas-fir seedlings germinating on exposed sites in Arizona and New Mexico did not survive without weekly precipitation.

The studies reported here were made under controlled greenhouse conditions to supplement field observations. Germination, initial survival, and early growth of seedlings were compared under watering treatments selected to represent the precipitation patterns most common on typical Douglas-fir sites in central Colorado[2].

Methods and Materials

Seed Source

Rocky Mountain Douglas-fir seed was collected locally from the Pike National Forest in 1973 and stored at 4°C. Average laboratory germination was 63%.

Soil and Seeding

Forest soil from 7,800 feet (2,377 m) elevation on the Manitou Experimental Forest was used. It is a coarse sandy-loam developed from Pikes Peak granite and covers much of the Experimental Forest (Marcus 1973, Retzer[3]). Moisture holding capacities at ⅓ and 15 bars determined in the laboratory, were approximately 24% and 13%, respectively. The soil was screened through 4-mesh hardware cloth, thoroughly mixed and placed in pots—7 inches (18 cm) deep and 6 inches (15 cm) in diameter—which were soaked to saturation twice a day for 3 days. Twenty seeds were then sown on the surface of the soil in each pot. All pots were again soaked to insure soil moisture was near saturation before watering treatments were begun. A total of 150 pots were prepared.

[2]*USDA Forest Service weather records for a 35-year period (1941-75) from the Manitou Experimental Forest, Colorado (records on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.) indicate that average precipitation for the months May and June (critical months for germination and initial seedling establishment) is 1.90 and 1.65 inches (4.8 and 4.2 cm) respectively. Precipitation for these months, generally ranging from 0.14 to 5.05 inches per month (0.4 to 12.9 cm), is most likely to fall in either several small storms of 0.25 inch (0.6 cm) or less, or in one or two larger storms.*

[3]*Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. 18 p. [Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.]*

Experimental Design and Treatment

The study consisted of two experiments. In experiment A, pots received 0.0, 0.5, 1.0, 1.5, or 2.0 inches (0.0, 1.3, 2.5, 3.8, or 5.1 cm) of water monthly, uniformly distributed throughout the month in applications of 0.25 inch (0.6 cm). In experiment B, pots received the assigned level of water once a month. Both experiments were arranged in a randomized block design with 15 replications.

Greenhouse Environment

Environment in the greenhouse at Fort Collins, Colo. was maintained as closely as possible to average field conditions during the growing season on north aspects on the Manitou Experimental Forest. Air temperatures were 70°F (21°C) day and 40°F (4°C) night. The photoperiod was 16 hours of natural and artificial light; temperature changes coincided with photoperiod. Relative humidity was varied from 20% to 30% (day) to 70% to 80% (night). The high light intensity—up to 12,000 footcandles (fc, 129,000 lx)—associated with openings in the forest cover on the Manitou Experimental Forest could not be reached in the greenhouse. The normally lower light intensity at 5,000 feet (1,524 m) elevation was further reduced by the greenhouse glass, so that light intensity inside the greenhouse varied from 3,000 fc on cloudy days to about 5,000 fc on clear days.

Measurements and Analyses

Number of germinating seeds, number of surviving seedlings, and cause of mortality were recorded twice a week. At the end of 20 weeks, the soil was carefully washed from the roots of all live seedlings, and the top height and root length was measured to the nearest millimeter. The tissue then was ovendried for 24 hours at 100°C and weighed to the closest 0.1 mg.

Germination and survival were expressed as a percent of the number of seeds sown per pot; top height, root length, and total seedling dry weight were expressed as means of surviving seedlings per pot. Differences due to treatments were tested for significance by analyses of variance with arcsine transformation for percentage data. Tukey's method of simultaneous confidence intervals was used to determine which treatment differences were significant (Graybill 1976).

Results

Germination

In experiment A (water uniformly distributed during the month), total germination increased from 25% to 63% as the amount of water increased from none to 2.0 inches per month (fig. 1). Germination was not significantly increased until 1.0 inch or more of water was applied; the 2.0 inches per month had a significant increase over the 1.0 and 1.5 inches per month ($\alpha = 0.05 \leq \alpha < 0.10$).

In experiment B (water applied once a month), germination was not affected by increasing amounts of water. Total germination at the no water level was 23% and ranged from 18% to 24% at other watering levels (fig. 1).

Length of Germination Period

The length of time over which seedlings emerged was affected very little by either the distribution or amount of water received. In both experiments, germination began in about 14 days and was generally completed 28 days after sowing. In experiment A, germination occurred up to 42 days after sowing, with 1.0 inch or more of water per month. In experiment B, some delayed germination occurred following the second and third applications of water (fig. 2).

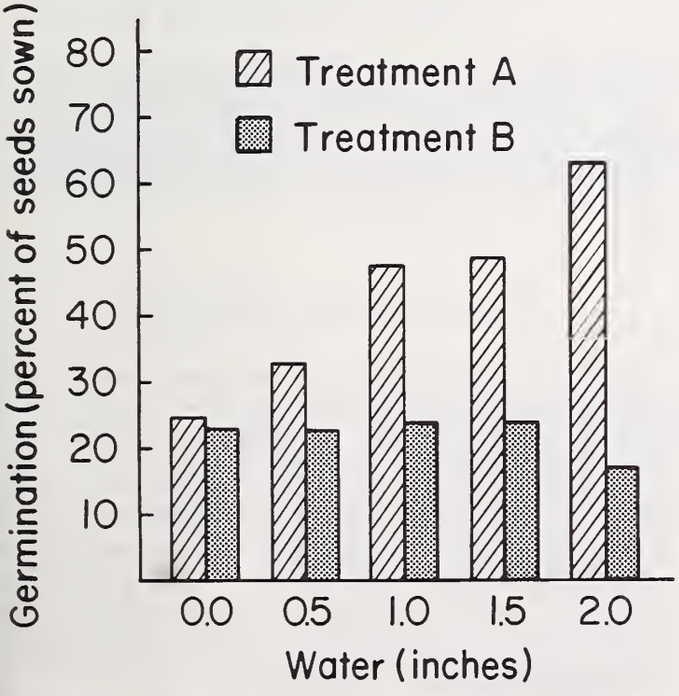

Figure 1.—Total germination in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Seedling Survival

Number of seedlings surviving after 20 weeks was related to both amount and distribution of water. When water was evenly distributed during the month, 1.0 inch monthly was required to sustain any significant survival—34% (fig. 3). Significantly more seedlings survived at 2.0 inches of water (55%) than at 1.0- and 1.5-inch levels ($\alpha = 0.05$). In contrast, few seedlings survived when water was applied only once a month. Survival percentages at the 1.0 inch or more level were not significantly different, ranging from 9% to 14% (fig. 3).

Causes of Mortality

In experiment A, drought was the principal cause of mortality at all levels of water, except 2.0 inches (table 1). Damping-off was an important cause of mortality at 1.5 inches or more. At these higher water levels, losses also resulted from failure to establish—the radicle emerged from the seedcoat and did not develop further, either because the seeds could not absorb sufficient water for the radicle to become rooted or seeds did not have enough germination vigor to complete establishment.

In experiment B, drought was the major cause of mortality at all treatment levels (table 1). Seedling losses from damping-off were important at 1.0 inch or more. Mortality from failure to establish was important but variable, and not necessarily related to amount of water received.

Seedling Growth

Plant growth for the two water distributions could not be compared statistically; however, except for higher seedling biomass at 2.0 inches per month in experiment A, it would appear that growth was about the same in both treatments. Seedling growth data for 0.5 inch per month were not included in the analyses in either experiment A or B because of poor survival.

With even distribution of water, seedling growth—total plant dry weight, top height, root elongation, and root/shoot ratio—appeared to increase with an increase in the amount of water applied; however, growth was not significantly affected except at 2.0 inches per month, where the seedlings were significantly heavier than either the 1.0 or 1.5 inches per month ($\alpha = 0.05$, table 2).

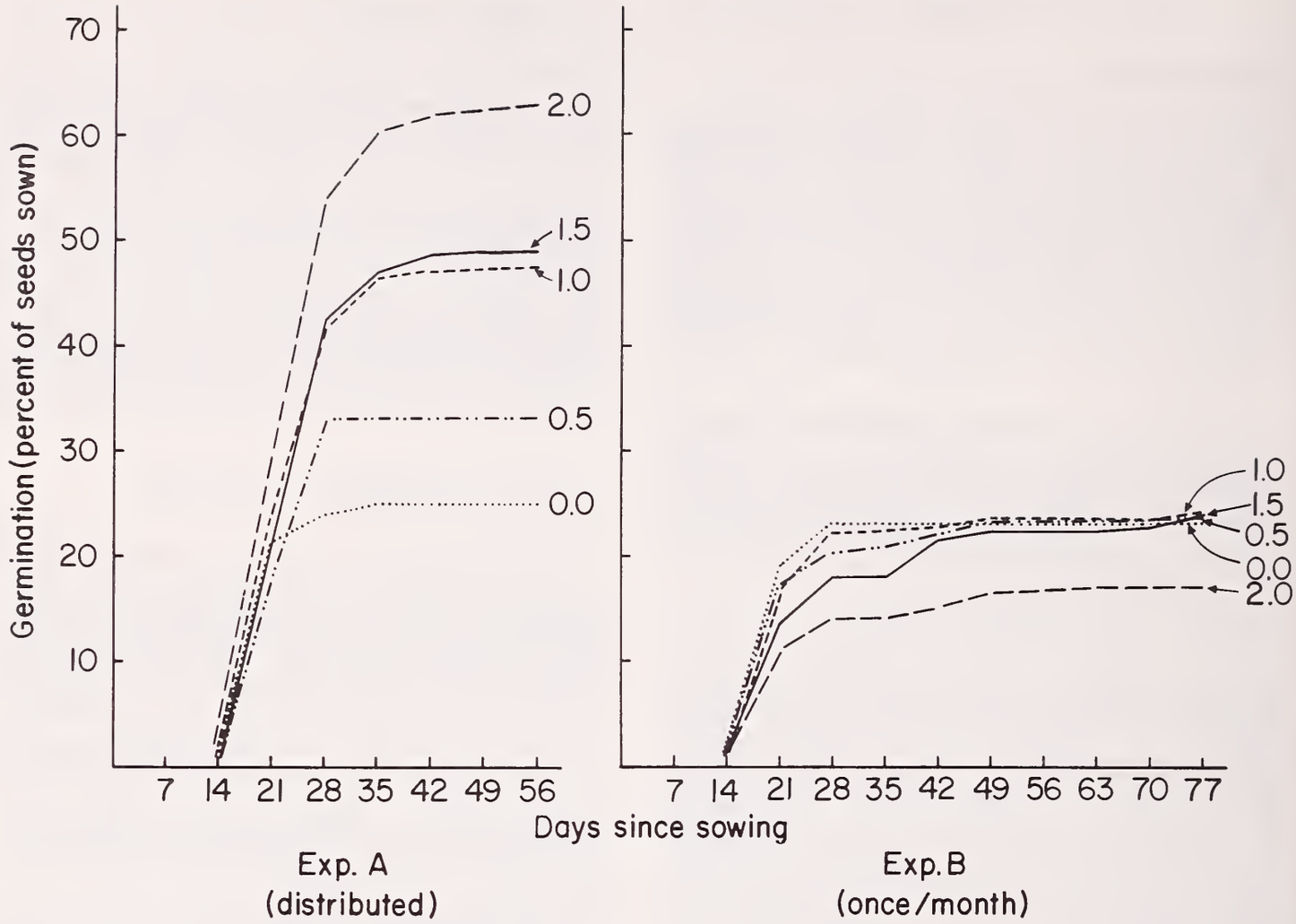

Figure 2.—Length of germination period in relation to water (Inches) amounts and distribution.

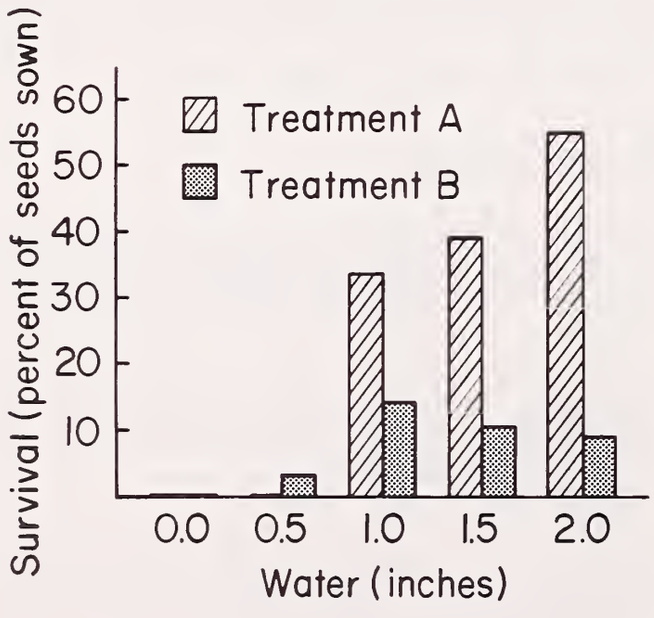

Figure 3.—Seedling survival after 20 weeks in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

When water was applied once a month, seedling growth was not significantly affected by amount of water received except at 2.0 inches/month, where seedlings were taller and root/shoot ratios were smaller ($\alpha = 0.05$, table 2).

Discussion and Conclusions

The greenhouse environment was more favorable to germination, survival, and growth than natural conditions. It is difficult, therefore, to extrapolate results from the greenhouse to the field. Nevertheless, certain inferences can be drawn from these experiments, combined with observations in the field, concerning the effects of amount and distribution of precipitation on natural regeneration of Douglas-fir in the central and southern Rocky Mountains.

Assuming that adequate seed is available and seedbed conditions are favorable, more seedlings

Table 1.— Percent total mortality, by cause, of greenhouse-sown Douglas-fir seedlings watered at predetermined intervals during the month (A); and watered once a month (B).

Monthly amount of water		Drought		Damping-off		Failure to establish		Other causes	
		A	B	A	B	A	B	A	B
in	*cm*								
0.0	(0.0)	98.6	92.8	1.4	1.4	0.0	5.8	0.0	0.0
0.5	(1.3)	94.0	76.3	3.0	5.1	3.0	16.9	0.0	1.7
1.0	(2.5)	87.5	69.0	5.0	13.8	7.5	17.2	0.0	0.0
1.5	(3.8)	46.7	63.1	30.0	31.6	13.3	5.3	10.0	0.0
2.0	(5.1)	20.8	58.3	33.3	25.0	29.2	16.7	16.7	0.0
Aver.		82.0	74.0	9.2	13.9	7.3	11.7	1.5	0.4

emerge with frequent showers than with one or two larger storms. At least 1 inch per month or more of well-distributed rainfall is necessary to provide adequate germination; whereas, if monthly rainfall is poorly distributed, germination is inadequate even at 2 inches per month (fig. 1). Most germination is completed in 30 days, whether precipitation is well distributed or occurs in only one or two storms (fig. 2).

At least 1 inch of evenly distributed precipitation is needed each month before seedlings survive in significant numbers and additional rainfall further increases survival. However, seedling survival is inadequate with infrequent precipitation even at 2 inches per month (fig. 3).

Distribution of precipitation does not seem to have an important effect on size and biomass of Douglas-fir seedlings that survive the first growing season. However, the amount of rainfall can affect seedling growth since, at 2 inches of rainfall per month, seedling biomass was greater with well-distributed precipitation, and seedlings were taller when water was applied as in one major storm per month. However, these seedling growth measurements are probably not comparable to field-grown seedlings, since average top height was about 1½ times and root length about 2½ times greater than field-grown, first-season seedlings (Jones 1971).

In this study, precipitation has been considered as an independent variable. Regeneration success is affected by many other environmental factors and their interactions, which must be evaluated before the effectiveness of a single factor such as precipitation can be fully analyzed. It is apparent, however, that under certain conditions, the amount and distribution of precipitation can be a major factor in the establishment of Rocky Mountain Douglas-fir seedlings.

Table 2.— Average growth of greenhouse-grown Douglas-fir seedlings watered at predetermined intervals during the month, and watered once a month. (Means for each variable with common or no subscripts are statistically homogeneous at $\alpha = 0.05$)

Monthly water treatment	Dry weight		Seedling height		Root length		Root/shoot ratio	
	A	B	A	B	A	B	A	B
in	*mg*		*mm*		*mm*			
1.0	38.6a	45.0	37.9	39.0a	174.6	230.8	4.64	5.99a
1.5	50.1a	45.4	39.7	35.4a	191.3	232.1	4.84	6.66a
2.0	63.4b	46.5	39.7	41.8b	205.3	193.2	5.25	4.67b

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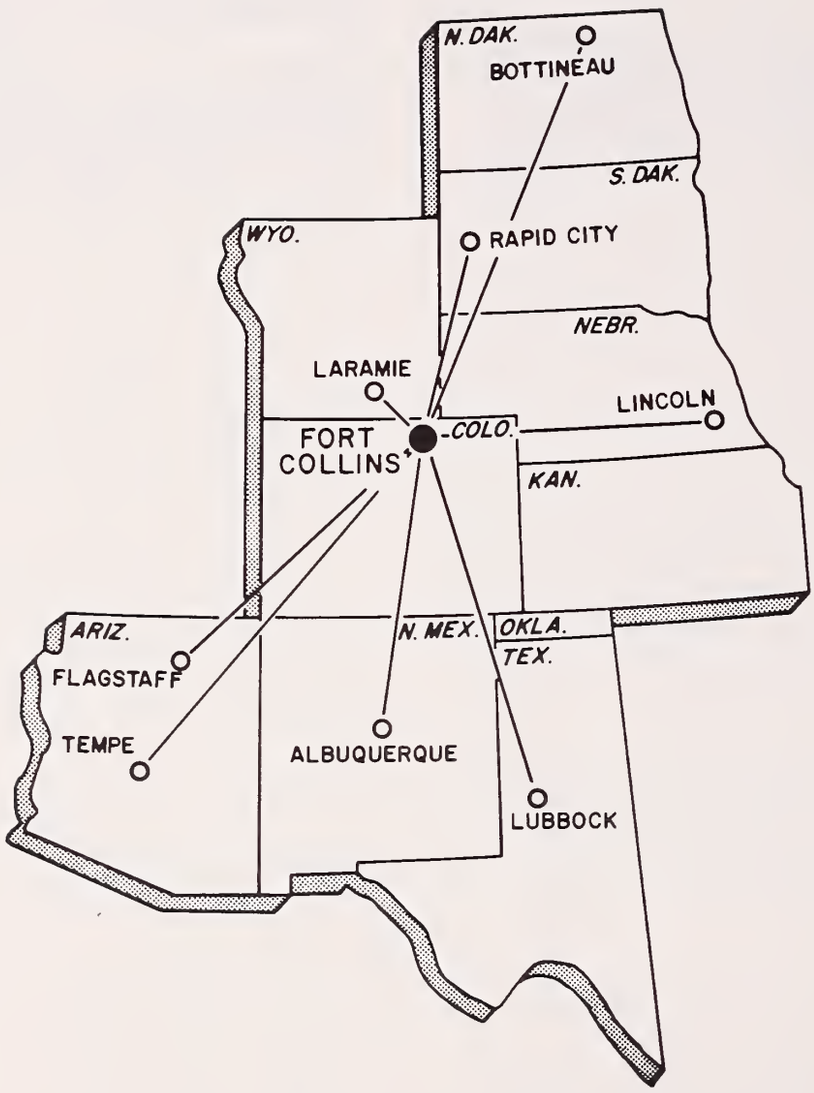
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